

Innovative Fresh Water Production Process for Fossil Fuels Plants

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The development of an innovative diffusion driven desalination (DDD) plant to produce fresh water and replace cooling towers in existing or future steam driven power plants is presented. Desalination is achieved by spraying heated saline water over a packed bed in a diffusion tower and low humidity air is blown through the packed bed from the bottom. As the falling liquid film of saline water forms over the packing material it contacts a turbulent low humidity air stream. Heat and mass transfer principles govern the evaporation of liquid water and humidification of the air stream. The advantage of using this process is that it requires an energy input with a low temperature or low thermodynamic availability. The energy picked up by the main condenser cooling water from low-pressure steam in a power plant is very well suited for the DDD process. Therefore, the energy used to drive the desalination process is energy that would have otherwise been dissipated in the environment. A diffusion driven desalination plant operating in conjunction with a steam driven power plant would allow the power plant to become a net producer of fresh water rather than being a consumer.

A detailed thermodynamic analysis of the process has been thoroughly explored. The parameters that govern the thermodynamic performance of the process are the ratio of the high to low temperature in the system, the air to feed water flow rate ratio through the diffusion tower, and the inlet and exit air conditions to the diffusion tower. As an example of system performance, a 100 MW steam driven power plant operating with 2" Hg vacuum in the main condenser is considered, in which 140 MW of energy is available at 93° C from the low pressure condensing steam. If the saline cooling water rises to 60° C and is then discharged to a DDD plant, there exists the potential to produce as much as 18 million gallons of fresh water per day. Since the operating temperature of the DDD plant is low, inexpensive materials may be used in construction, which will minimize the capital investment required to fabricate a plant.

There are two main components of the DDD plant that will govern its performance, 1) a diffusion tower, where evaporation occurs and 2) a direct contact condenser, where fresh water is

produced. In order to achieve the predicted performance based on thermodynamic considerations, the diffusion tower and direct contact condenser must be designed such that the fluids exiting achieve the design thermodynamic states. The heat and mass transfer process through the diffusion tower is very complex and the existing literature does not provide sufficient framework for the diffusion tower design. A detailed analysis describing the heat and mass transfer and solution procedure required to design and optimize the DDD process diffusion tower has been formulated. The formulation is based on a two-fluid film model in which conservation equations for mass and energy are applied to a differential control volume. Three differential equations result: 1) mass transfer equation, 2) energy equation for the liquid film, and 3) energy equation for the vapor mixture. These equations are simplified so that only gradients in the direction of the tower are included. Therefore, closure correlations are required. The mass transfer correlations of Onda (1959) and corresponding heat and mass transfer analogy are used to close the set of three coupled ordinary differential equations. These three differential equations are solved using a finite difference marching technique and are used to evaluate the required tower height needed to achieve the design exit conditions. Once the tower height is calculated, a standard correlation is used to compute the air pressure drop across the packed bed. This analysis will allow the diffusion tower to be designed such that the pumping power required to drive the fluids through it tower is minimized.

A laboratory scale DDD plant is being fabricated to validate the modeling effort. One shortcoming of the modeling effort is that dimensionless heat transfer correlations for air/water film flow through a packed tower are not available. The current modeling effort relies on the heat and mass transfer analogy. In order to overcome this shortcoming, detailed heat and mass transfer measurements will be conducted within the diffusion tower in order to improve the empirical correlations required for the computational analysis. In addition, a tandem computational fluid dynamics effort is being conducted in order to guide the parametric range to be covered by experiments. Details of the experimental progress will be published in future work.